Process Plant and Equipment UP-TIME

The essential engineering maintainers and operators need to keep plant reliability up and operating costs down.

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Maintenance Systems

Reliability Centered Maintenance - what is it?

What you will learn from this article.

- Meanings of 'loss of function', 'failure modes' and 'failure patterns'.
- RCM provides a way to select the best maintenance strategy for new plant and equipment.
- PM Optimisation, a shorter version of RCM, is used on existing plant and equipment with sufficient known failure history.
- The RCM process and procedure is introduced.
- How to put RCM outcomes into workplace practice.

Reliability Centered Maintenance (RCM) is one of the great developments in asset management. It is a methodology which studies a piece of plant or equipment in detail, predicts how it can fail, and puts into place the best maintenance strategy to prevent failure, or minimise losses from failure.

LOSS OF FUNCTION AND EQUIPMENT FAILURE

A thing fails when it can no longer perform its intended duty. When a pump (or any equipment) cannot do its duty at the designed rate it has a loss of function. If some product is still coming through, people may decide it is sufficient and leave it in service a while longer. Whenever equipment does not satisfy the minimum duty requirement it is considered to have failed. RCM provides a way to detect loss of function before failure.

The aim of Reliability Centered Maintenance is to -

- use equipment and process-knowledgeable people to work out how many 'reasonably likely' ways a piece of equipment can loose its function
- use production and process-knowledgeable people to determine the effects and consequences resulting from each loss of function
- decide if the consequences of a failure need to be prevented
- use equipment, process and maintenance-knowledgeable people to come up with effective proactive methods of preventing the failure or agree that no actions will be performed to prevent the failure
- use maintenance and operations-knowledgeable people to turn the method into situation-practical actions for the operators and maintainers
- buy the necessary equipment to detect the early onset of loss of function
- teach supervisors, leading hands, operators and maintainers the correct use of the equipment
- let people know what to do once loss of failure is noted

FAILURE PATTERNS and FAILURE MODES

The initiation of a failure has been found to follow one of the six probability patterns shown in Figure No. 1. Evidence from the airline industry indicates that patterns D, E and F represent 89% of failures, with pattern F alone representing 68%. What the shapes highlight is that for most equipment, failure is not age related but can occur at any time.

A piece of equipment can only fail in a limited number of ways. The ways in which it can fail are known as its 'failure modes'. The RCM process finds the likely failure modes and lets people decide about what to do to detect them early on, so the problem can be corrected before failure. Where the consequences of a failure are unimportant the equipment is left to run to destruction and is then replaced. Where the consequence of failure is important, measures are put into place to prevent failure. This includes condition monitoring, physical inspection, and regular overhauls. If necessary, the equipment is redesigned to remove the failure mode.

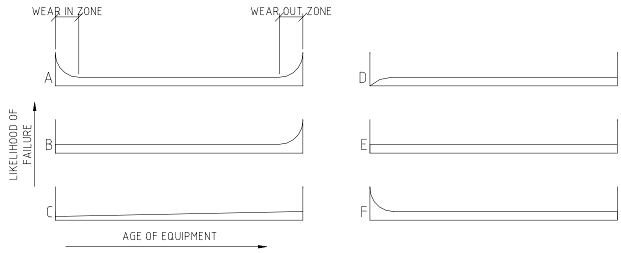

Figure No. 1 The six failure patterns.

THE RCM PROCESS AND PROCEDURES

RCM uses a team of experienced and knowledgeable people to answers seven questions and come up with a strategy to maintain equipment function. The questions are:

- What are the functions and associated performance standards of the asset in its present operating context?
- In what ways does it fail to fulfill its functions?
- What causes each functional failure?
- What happens when each failure occurs?
- In what way does the failure matter?
- What can be done to predict or prevent each failure?
- What if a suitable proactive tack can not be found?

If the frequency of failure is unknown, research is conducted to find out how often the item is likely to break. Sources of failure data include original equipment manufacturers, equipment life databases, other same equipment users and other similar equipment.

The review process produces proactive tasks that offer effective means of detecting or preventing failure for each asset. The next step is to determine how often these tasks are to be performed so that loss of function is detected early enough to prevent complete failure. The test intervals are selected to be short enough to fit between the point-in-time failure is initiated and the point-in-time the item is considered failed. This requires us to predict the failure.

PM OPTIMISATION

PM Optimisation is a shorter version of RCM used on existing plants with sufficient history on known failure modes. Instead of starting with the first question, PM Optimisation starts with the third question because the failure modes for the equipment are already known from site-specific historical data. It greatly shortens the entire process.

IMPLEMENTING RCM IN THE WORKPLACE

After the decisions of how to monitor the failure modes are made, they need to be converted into actions which can be performed at the plant user and maintainer level in the company. This means new procedures, new equipment, new training and new scheduling requirements have to be developed, communicated and practiced.

The transfer from office-logic to plant-logic is where the RCM process often becomes unglued and fails. Plant users and

maintainers do not care too much about ‘highbrow ideas’ imposed on them by their managers and outside consultants.

In order for the transfer of RCM outcomes to proceed successfully into the work place every supervisor and leading hand in operations and maintenance must be supportive of the required changes to work practices. Without commitment from these levels in the organisation the implementation success of RCM will be poor.

You get commitment by involving people in the process and its outcomes. The first people (but not the only people) to train in the RCA approach are the supervisors and leading hands. The first people to train in the new technologies to be introduced into the work place are the supervisors and leading hands. And the first people to ask about the best way to get RCM implemented in the work place are the supervisors and leading hands.

Mike Sondalini – Maintenance Engineer

References: John Moubray, RCM II Reliability Centered Maintenance Edition 2, Industrial Press Inc.

Process Control Talk

Electric Motor Current Protection Saves Your Plant.

What you will learn from this article.

- Electric motor power current draw reflects the motor’s working load.
- The electric current through a power cable can be measured using the strength of the magnetic field created around the cable.
- Under-current detection protects against loss of load situations.
- Over-current detection protects against over-load situations.

A lot of equipment failure results from just simple, plain mistakes, sometimes from unintentional forgetfulness, sometimes from ‘short-cut’ taking and sometimes because of ignorance of the consequences. The result is plant destroyed at great cost and inconvenience. But for plant being driven by an electric motor there is something that can be done very cheaply to protect it from being run outside of its design 'envelope'.

ELECTRIC MOTOR CURRENT DRAW

The power required to operate a 3-phase induction electric motor depends on the torque load on the motor. Low load means a low power draw and causes a low current draw, high load leads to a high power draw and a high current draw. Low load means the motor is turning near full speed and doing little work while drawing little power, high load means the motor is turning at lesser speed and working hard while causing a greater power draw. Overload means the motor has too much load and cannot turn at all. Figure No. 1 shows a 3-phase induction motor performance characteristics.

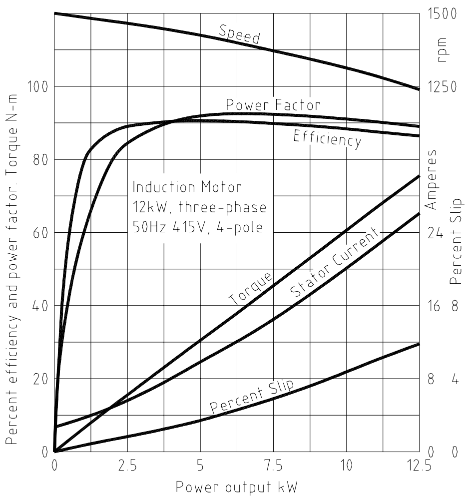

Figure No 1. Electric motor characteristics

The stator current draw characteristic is a good variable to monitor and use for a decision to stop the motor before it gets damaged. Anything attached to the motor will also stop. In this fashion the equipment is protected from any condition that produces a low power draw or any condition that causes a high power draw.

DETECTING CHANGING ELECTRIC CURRENT

When an electric current flows through a wire it produces a magnetic field around the wire. The greater the current, the stronger the magnetic field. The magnetic field will induce electrical fields and cause current to flow in neighbouring wires. This phenomenon causes problems for process logic computer (PLC) equipment and field equipment communications because the electrical fields can interrupt signals sent between equipment and computer. In this case communication cabling is specially shielded away from power cabling. However the phenomenon is useful as a means of monitoring electric power draw.

By installing a current transformer onto a power cable the transformer develops its own current which is proportional to the current in the cable being monitored. Using a current transformer means there no wires to cut, the transformer is low cost, readily available and installation is quick. When coupled with a metering relay and a timer it is possible to turn off the power to a motor when the current goes outside set limits for a given period of time. If the limits are set to the current draw at maximum and minimum working situations and the motor is turned off when the limits are passed then the motor is protected from abnormal load conditions.

The use of a current transformer is but one way to detect the presence of an electrical current. Other methods are also available to detect electrical current and involve installing the monitoring device into the electrical circuit.

UNDER-CURRENT SITUATIONS

When a motor is freewheeling, or it is very lightly loaded, the current required to just turn the motor is only a small portion of the full load current. If such a situation develops when a motor in operation it is probably because something abnormal has occurred.

A typical low-load situation arises when centrifugal pumps are deadheaded against a closed discharge valve or if a downstream suction valve is shut and the pump is cavitating because it is starved of liquid. In this case undercurrent protection would detect the low load on the motor and turn it off. If the pump had a mechanical seal it would be protected from damage before loss of lubricating fluid across the seal faces destroys the seal.

Another situation where undercurrent protection would be useful is in the detection of unloaded conveyors or bucket elevators. They could be turned off automatically after a period of time. Anytime the components in a drive train fail, for example the shaft coupling breaks, or a drive shaft breaks or drive belts come off or snap, the motor load would suddenly drop and the fall in load current could be used to trigger a shutdown and/or an alarm.

OVER-CURRENT AND OVERLOAD SITUATIONS

As the load on an electric motor increases, the spinning rotor starts to slip more and slow down. The electric current draw rises as the motor tries to maintain speed. The higher current flow causes more heat to develop inside the motor. The heat builds up and can destroy the motor’s internals. The motor fails due to being overloaded. Here again current detection can be used to shut the motor down and protect it and/or raise an alarm.

Overloads are likely in bulk materials handling situations such as bucket elevators and screw feeders. Where equipment has to combat a dragging, digging or scraping action as part of the process, sudden overloads should be expected. Over-load protection should be incorporated into the original design.

ALLOW FOR THE OPERATING REQUIREMENTS

There are times when motors are required to free wheel for a short period or there will be a short, temporary overload situation. An example is when a pump sending liquid into one tank is required to send liquid into an alternate tank. For a short period both tank’s valves may be closed. It is often better to keep the pump running for a few seconds against a deadhead rather than to put it off and restart it. In this case the motor current will intentionally drop low but do not want the undercurrent protection to stop the motor.

The timer is used to prevent the motor shutting down unnecessarily. Observations are made of normal operating duty current draws and delays to permit normal operation, such as high current draw at

start-up, are set into the timer. The current protection only activates after the timer counts out in the presence abnormal loads.

There is one issue to be weary of when using current protection. It is possible to have a 'false' load on the motor. As long as a motor experiences 'normal' loads the current stays within the permitted operating band. Should this load be the result of a part failing, e.g. a collapsed bearing or a slipping vee-belt, then the current could still be in its working band and the protection will not operate.

Current protection is a cheap, simple way to protect your equipment against those unexpected and unforeseeable errors that happen.

Mike Sondalini – Equipment Longevity Engineer

References: A. Mychael, Electric Circuits and Machines Edition 2, McGraw-Hill Book Company

Spread Forces Throughout Equipment and Reduce Breakdowns

What you will learn from this article.

- How forces are distributed through an object.
- Force diagrams are used to represent forces on an object.
- Position and direction of a force determines the type of stress.
- How to redistribute force in a structure.

Why don't you fall to the ground when you sit in a chair? Why doesn't the roof fall in on top of you? We don't expect these sorts of things to happen. But at times chairs fail and people fall to the ground and at times roofs fall on people. When structures are put under sufficient stress they will fail.

FORCES IN STRUCTURES

A structure is anything solid. When an object is solid it can take a load. When a load is applied to a structure it is stressed. The type and extent of the stress depends on the amount of load, the position of the load, the direction of the load, the shape of the structure and the properties of the material in the structure. A structure must be designed to take all the stresses created by the loads it is to carry.

The 'A' frame in Figure No. 1 is a structure under load. Let us say that the load is a workman with his tool kit. The 'A' frame supports a walkway and the man is walking to his next job. The weights of the man, his tool kit and section of platform above the frame total 200 kg. We will observe the effects of the force transmitted through the frame.

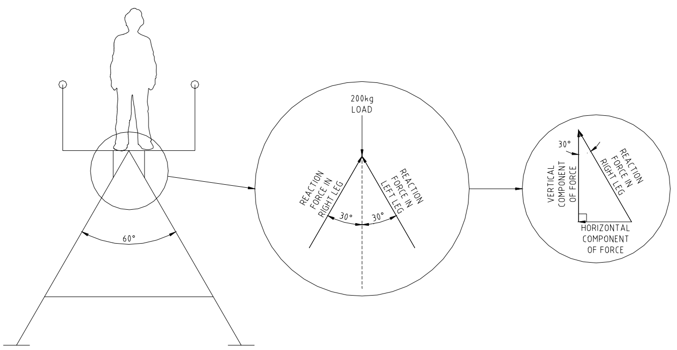

Figure No. 1 An 'A' frame structure under load.

We first draw the frame on paper as a single line diagram and then apply the load to the frame. The line-diagram is a representation, a symbol, of the actual frame. We do not yet know the cross-sectional shape and size of the frame members. The members could be round or square solid bar, a pipe, a rectangular hollow section, an angle iron or an I-beam. Nor do we know what materials to use. We could use butter, plastic, wood, steel, concrete or aluminium. The choice of material and shape will come out of our investigation and it will depend on the stress it can handle.

FORCE DIAGRAMS

To determine the size and direction of the forces in each member we replace the single-line diagram members by imaginary force lines that represent the members. At the top connection of the 'A' frame two members come together. This connection is shown as a force diagram in the exploded view in Figure No. 1. The two members equally share the weight of the man, tool kit and walkway. The connection is in equilibrium, that is, in a state of balance, with upward forces matching downward forces.

The direction of weight is always towards the center of Earth's gravity. But each of the two legs taking the weight point away from the Earth's center of gravity by 30^o. Force cannot be transferred through open space but only through a solid structure. The forces in the legs can only be in the material of the legs. This is shown in the force diagram by the lines at 30^o to the load line.

The proportion of weight in each leg is calculated using trigonometry. The triangle of force shown in the second balloon Figure No. 1 show the vertical and horizontal force components that make up the load in the right leg. Since the downward and upward forces must be equal for the frame to be in equilibrium and not collapse, we put the downward forces equal to the upward force but in opposite directions. The equation can be written as –

$$200 \text{ kg} = F_{\text{left leg}} \text{ x Cosine } 30^o + F_{\text{right leg}} \text{ x Cosine } 30^o$$

At the top connection each leg experiences 115.5 kg weight through its material. To convert this weigh to a force it must be multiplied by gravity, which on Earth is 9.81 m/sec/sec (say 10 m/sec/sec for simplicity of multiplication). The force in each leg is 1150 Newton (A Newton = 1 kg x 1 m/sec/sec).

FORCES CAUSE STRESS

A force acting on a solid produces stresses in the solid. Stress is defined as the force acting on an area square to the direction of the force. Its formula is

Stress = Force / Area (Newton/meter x meter)

Its unit of measurement is the Pascal (Pa) and one Pascal equals a force of one Newton over one square meter of area.

The formula presents three options to handle stress. The first is to reduce the size of the force, the second is to increase the available area over which the force can act and the third is to use materials with a higher breaking stress than the stresses the load produces.

There are three common types of stress. The first is a tensile stress and is produced when a force pulls a thing apart. The second is a compressive stress and results when a force is acting to squash a thing together. The third type of stress is a shear stress and is the result of a force producing a tearing action through the object. Figure No. 2 shows examples of the three types of stress.

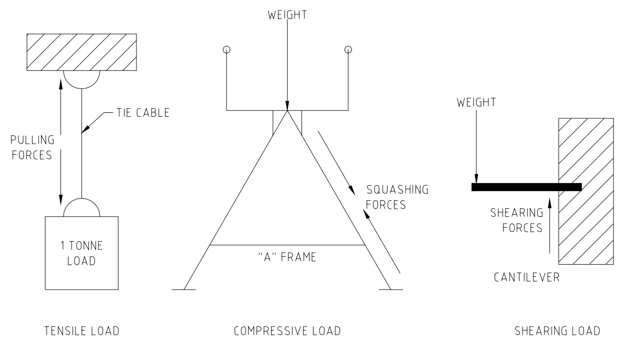

Figure No. 2 Applying a force causes a stress

The position and direction of the force determines which stresses occur. Shear stress causes the greatest problem in engineering materials. In selecting the type of material and its size for the 'A' frame, all three stresses have to be determined. Once the maximum amount of each type of stress is know the correct material type and cross-section can be chosen to handle the stress without failing.

REDISTRIBUTING FORCES

Figure No. 3 shows a work place situation. A flange is welded to a pipe used as an agitator shaft in a tank. The paddles at the bottom of the tank wobble as they turn and the shaft is bent from side to side. The weld between the flange and shaft is subjected to the highest stress concentration and has been known to fail by cracking. This is a situation where the amount of weld cross-sectional area

available to take the load is not sufficient to handle the combined effect of the load itself and the metal fatigue produced by the fluctuating stresses from the shaft wobble as it turns.

To lower the stresses at the weld it is necessary to share and spread the load over more area. One option is to add gussets to the flange and shaft as shown in the second drawing of Figure No. 3. Another option would be to user a a larger diameter pipe. A third option would be to use a material that can take higher stress before it fails.

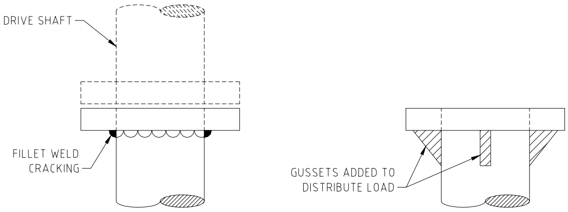

Figure No. 3. Using gussets to redistribute stresses.

The gussets provide more cross-sectional area for the loads to act over by taking the loads away from the weld and redistributing them along the pipe and across the flange.

If faced with situations where parts and equipment are failing from stresses produced by high loads or fatigue situations, look at ways to increase the area over which the load is applied.

Mike Sondalini – Equipment Longevity Engineer

References: PP Benham & FV Warnock, Mechanics of Solids and Structures, Pitman International
JL Meriam, Engineering Mechanics Vol. 1 Statics, John Wiley & Sons.

Cyclone Separators – an overview

What you will learn from this article.

- How cyclones and hydrocyclones work.
- Where cyclones are used.
- Design features that affect cyclones.
- How to get long life from cyclones.

A tornado can lift cars from the ground and hurl them hundreds of meters away. Chickens and ducks can be hurled kilometers away. The story of fish falling from the sky is explained by the power of a tornado to lift materials kilometers into the sky. The spinning vortex of air separates and segregates heavy and light objects. The heavy objects drop out sooner and the light objects are carried further. Cyclone separators and hydrocyclones work the same way.

DESIGN OF CYCLONE SEPARATORS

The most common type of cyclone separator is the tangential inlet, axial discharge style shown in Figure No. 1. The second often-used design is the axial inlet, axial discharge type which uses slanting vanes to start the air spinning. The tangential inlet cyclone covers a much larger range of throughput and particle sizes than the axial inlet design and is cheaper to make. Both work on the principle of using a spinning column of air to separate particles of different weights. A hydrocyclone spins a column of liquid instead of gas.
Cyclones are used to separate liquids and solids from a gas stream. Hydrocyclones separate solids from liquids or one liquid from another of different density. The inlet stream enters the top chamber at high velocity and spins around the inside wall of the chamber. Any material above the weight that can be held up by the moving stream is flung out to the wall of the chamber and begins to slide down to the bottom outlet.

The stream then spirals down the cyclone top and enters into the conical bottom as more comes in from behind. Since the cone tapers inward, the available volume to take the full stream decreases. The speed of the stream increases to keep a constant mass flow through the cyclone. The stream velocity is higher and spinning faster as it moves down the cone. So fast in fact, that the centrifugal forces on the smaller particles remaining in the stream overcome the carrying velocity and are flung out to the wall. As the stream moves down the cone the particles being separated out become smaller and smaller.

Have you seen cigarette smoke sucked out of a moving car window? It is a natural law that a moving stream of air produces reduced pressure at right angles to its direction of motion. The 'moving' air at the open window is at a lower pressure than the air in the car and the smoke is drawn to the window. The same law applies in a cyclone. The stream spinning against the inside wall of the cyclone produces a low-pressure area at right angles to its motion. The low-pressure area develops in the middle of the cyclone and becomes a reverse spiraling column of fast moving low-pressure gas exiting the outlet nozzle in the top chamber.

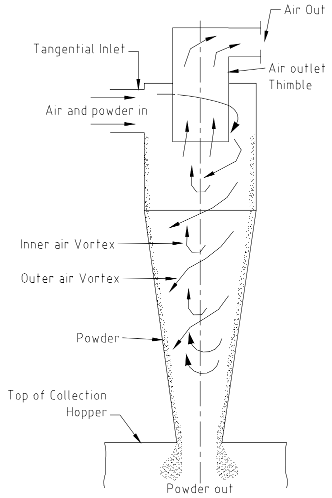

Figure No. 1 Tangential inlet cyclone showing gas flows

CRITICAL SHAPE AND FLOW PARAMETERS

The critical factors affecting cyclone operation are sufficiently high gas stream velocity, particle agglomeration characteristics (tendency to join and stick together) and cyclone diameter-to-length ratios of the top cylinder and cone. By altering the size ratios of the cyclone sections it is possible to design cyclones that will remove (cut) particles above a specific size/weight proportion.

CONFIGURATION OF A CYCLONE IN USE

A cyclone requires a high velocity, moving stream of gas to be consistently fed to it. A fan is used to push or suck the gas through the cyclone. The flow needs to be steady and not fluctuate otherwise the counter-moving vortexes within the cyclone cannot develop and be sustained.

The bottom outlet is required to be air tight so no air bleeds into the low-pressure central vortex. If air does leak through the bottom outlet the particles on the inside wall of the cyclone are re-entrained in the air steam and are sucked up the inside vortex and out the gas outlet nozzle. A rotary valve or an automated twin butterfly valve air-lock arrangement can be used on the bottom outlet. If a dustbin is installed on the bottom of the cyclone empty the bin regularly so the dust does not fill up and enter into the cyclone.

Cyclones can be run in series or in parallel. When in series they are often configured so that the first one takes out the big particles while the next takes out smaller particles. Series operation produces high-pressure drops and requires more powerful fans to force the stream through the system.

High particle velocities within the cyclone will wear away the walls. For aggressive materials the internal walls will require lining or use of a harder material than the particles. If rubber is selected check that the particle hardness and shape do not rip into the soft rubber. At times harder urethane plastics and even ceramic linings maybe required.

Mike Sondalini – Equipment Longevity Engineer

References: Muhammad E. Fayed & Lambert Otten, Handbook of Powder Science and Technology Chapter 15, 1997
Perry Robert H, Perry's Chemical Engineer's Handbook 1984, McGraw-Hill Book Co.

Humour, Questions & Money- November 2001

HUMOUR in your day.

- *M I N D T R A P* -

See if you can work out what is going on in these everyday stories. A warning - nothing is what is seems!
****

Mel Colly stared through the dirty soot-smeared window on the 26th floor of the office tower. Overcome with depression and gloom he slid the window open and jumped through it. It was a sheer drop outside the building to the ground. There was nothing to cushion his fall or slow his decent but upon landing he was miraculously unhurt.

How could he have survived?
****

A woman from Sydney, Australia married ten different men from that city, yet she did not break any laws. None of the men died, and she never divorced.

How was this possible?
****

It was raining but Charlie Brown went for a walk without an umbrella. He did not wear a hat and did not take refuge under a shelter; yet, not one hair on his head got wet.

How did Charlie do it?
****

Dee Septor, the famous magician, claimed to be able to throw a Ping-Pong ball so that it would go a short distance, come to a dead stop, and then reverse itself. He also said that he would not bounce the ball against any object nor tie anything to it.

What was Dee Septor's secret?
****

Answers
Mel was a window cleaner, and he stepped into the room from his hoist.
The Sydney woman was a celebrant, she conducted 10 marriage services.
Charlie walked from one room to another inside his house.
Dee threw the ping-pong ball up in the air.
****

Did you assume something about the stories when you read them? We all do it. Remember – nothing is what it seems like at first. People can be perfectly honest and tell the truth as they see it, but it will not be the whole story.

The only way to get even close to the whole truth is to go and check it yourself, making sure everyone involved tells you all that they know. If possible look for real evidence that confirms what they say. Maintenance has a lot to do with being a good detective.

QUESTIONS are important to ask.

If you have questions on any of the topics in this edition please e-mail them to us before the end of the month at mailto:info@feedforward.com.au and they will be answered in the next flyer.

MONEY comes to those who understand it.

Arkad, the richest man in Babylon, had during his life learnt the 7 secrets for accumulating wealth and now he told his eager listeners the fourth of these secrets.

The fourth cure for a lean purse was to make only those investments where your money would not be lost. He told the story of how he lost his entire first year's savings on his first investment. He saw a fast way to make money. He entrusted his hard earned 10% of income saved that first year to a bricklayer who was travelling to foreign shores and would buy him precious jewels to sell in Babylon.

The foreign traders sold the bricklayer bits of glass! Arkad was devastated. He wanted to get rich fast. He wanted quick wealth and was eager to do anything to get it. But in his haste he made a high-risk decision in ignorance and lost all.

But he learnt his lesson. The lesson being - What does a bricklayer know of buying jewels? Nothing! A bricklayer would be a good person to talk to about building houses but he was a poor choice to talk to about becoming wealthy from buying and selling jewels.

So Arkad determined that he would only invest his money with people that knew their business well and who had a reputable track record of returning the money and paying interest. But there was one more thing he had painfully, embarrassingly learnt he must first do before investing.

He realised he had first to become acquainted with the risks of the investment. Do not be too confident in your own knowledge of investing. Would you trust your money to bricklayers to buy jewels? Seek the advice of trustworthy, reputable and honest people who have already been making money from investments.

The fourth secret to wealth, in Arkad's words was, "*…Guard thy treasure from loss by investing only where thy principle is safe, where it may be reclaimed if desirable, and where thou will not fail to collect a fair rental. Consult with wise men. Secure the advice of those experienced in the profitable handling of gold. Let their wisdom protect thy treasure from unsafe investments.*"

You can find the right people to talk to if you look for them. They are in the business of providing investment advice. Do not go to people that want money to invest. You cannot get reputable investing advice from people looking for money.

You are responsible for your own money. If you want long term wealth that will stay with you, become the master of your own investment decision making.

Next month we will learn of the fifth of Arkad's secrets.

Regards, - *Mike Sondalini*

Reference: George S Clason, The Richest Man in Babylon, Bantam Books, 1976

Did you let your people miss something important today?

In the plant operation and maintenance game things happen fast! Time pressures cause people to take shortcuts. If the short cuts your people took today were a mistake, or there was a better way, how will you let them know what they should have done? Someone has to tell them!

That's where you make use of UP-TIME! Print off an article and pass it to them to read. If you need the complete set of 114 articles to-date you can order them from our resellers or us. You can see the full set of articles at our web site ______________________.

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